

# JIG PLATE AND END FACE POLISHING METHOD

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to a jig plate provided to an end face polishing machine, for holding an optical connector plug and an end face polishing method using the same.

### 2. Description of the Related Art

In order to reduce connection loss at a connector connecting part and to decrease reflected return light, general optical connectors used in optical communication and the like use an Angle physical contact (PC) connector in which the end face of an optical fiber held in a ferrule cylindrical member is polished together with the end face of the ferrule cylindrical member diagonally relative to a plane perpendicular to the axis of the optical fiber into a convex curve.

The Angle PC connector includes an optical connector plug formed of a ferrule cylindrical member for holding the optical fiber and a plug housing for holding the ferrule cylindrical member and an optical connector adapter for optically connecting the optical connector plugs inserted from opposite ends thereof.

When the opposed optical connector plugs are connected

through the optical connector adapter, the ferrule cylindrical member is held in the plug housing in a state in which the rotational movement about the axis of the ferrule cylindrical member is restricted in order to control the direction of eccentricity of the ferrule cylindrical member to reduce insertion loss.

The ferrule cylindrical members are held in the plug housing such that they are freely moved axially by a predetermined distance while being urged toward the axial end with respect to the plug housing and the end faces are brought into contact with each other for optical connection under a predetermined pressure in the optical connector adapter.

In order to hold the ferrule cylindrical member so as to be axially moved by a predetermined distance, an optical connector is proposed in which a key provided in the plug housing for controlling the rotational movement and a key groove provided in the flange of the ferrule are brought into engagement with each other and a predetermined space is provided between the key and the key groove so that the ferrule can move in the axial direction (for example, refer to Patent Document 1).

The ferrule cylindrical member of the optical connector plug and the end of the optical fiber are polished into a convex curve inclined relative to a plane perpendicular to the axis by using an end face polishing machine in which the

ferrule cylindrical member and a rotating and fluctuating polishing member are brought into contact with each other, with the optical connector plug in the above-described state.

The end face polishing machine includes a polishing plate having a polishing surface shaped in a circular cone that increases in height from the outer periphery toward the center, with the angle formed by the rotation axis (an axis of rotation or an axis of revolution) and a vertical plane being a very small angle  $\Delta$  and a jig plate for holding the optical connector plug in the opposite position relative to the polishing plate. The jig plate is moved toward the polishing plate to thereby bring the end of the ferrule of the optical connector plug into contact with the polishing member on the polishing plate, thereby performing the Angle PC polishing (for example, refer to Patent Document 2).

The jig plate used in the known end face polishing machine, however, holds the plug housing of the optical connector plug. Therefore, when the ferrule cylindrical member is brought into contact with the rotating and fluctuating polishing member at a predetermined angle, the ferrule is displaced in the direction of rotation around the axis of the optical fiber because of a space formed between the plug housing and the flange of the ferrule. This produces the problem that the direction of inclination of the polished convex curve of the ferrule cylindrical member does not pass

through the axis of the optical fiber, so that the center of polishing in contact with the polishing member comes out of the center of the optical fiber, and thus the center of curvature formed on the end face shifts from the axis of the optical fiber in the direction perpendicular to the direction of inclination of the end face.

In the Angle PC polishing, since the polishing plate is rotated and fluctuated, the ferrule cylindrical member is polished by the polishing member to form a trochoid trail. This increases the amount of polishing on the end face of the ferrule cylindrical member in the direction of rotation of the polishing plate in the region of a trail described by the ferrule cylindrical member moving upward on the polishing surface inclined from the center toward the rim. On the other hand, this decreases the amount of polishing on the face opposite to the direction of rotation of the polishing plate in the region of a trail described by the ferrule cylindrical member moving downward on the polishing surface inclined from the rim toward the center. This produces the problem that the amount of polishing on the face of the ferrule cylindrical member cannot be even, thereby causing unsymmetrical wear, so that the center of curvature of the face shifts from the central axis of the optical fiber in the direction perpendicular to the direction of inclination of the end face.

[Patent Document 1]

JP-A-1-216304 (p. 2, Fig. 6)

[Patent Document 2]

JP-A-8-112745 (p. 3, Fig. 1)

#### SUMMARY OF THE INVENTION

Accordingly, in view of the above problems, the present invention provides a jig plate and an end face polishing method capable of reducing the displacement between the center of curvature of the end face of a ferrule cylindrical member that is diagonally PC-polished and the central axis of an optical fiber, thereby reducing insertion loss.

In order to solve the above problems, a jig plate according to embodiments of the present invention is provided which is opposed to a rotating and fluctuating polishing plate of an end face polishing machine for polishing the end face of a ferrule cylindrical member that holds the end of an optical fiber, for polishing the face of the ferrule cylindrical member into a convex curve inclined with respect to a plane perpendicular to the axis, with the ferrule cylindrical member brought into contact with the polishing plate at a predetermined angle. A jig plate body having a mounting part to the end face polishing machine includes a holding part for detachably holding an optical connector plug, wherein the holding part holds the optical connector plug while correcting the target inclining direction of the

polished convex curve of the ferrule cylindrical member so as to turn to a direction opposite to the rotating direction of the polishing plate with respect to a plane including the center of the jig plate body and the axis of the optical fiber so that the inclining direction of the polished convex curve of the ferrule cylindrical member held by the optical connector plug coincides with the reference direction of the optical connector plug.

In a jig plate according to embodiments of the present invention, the reference direction of the optical connector plug is preferably determined with the outer periphery of the optical connector plug as the reference.

In a jig plate according to embodiments of the present invention, the reference direction of the optical connector plug is preferably determined depending on the direction of a location key provided to the optical connector plug.

In a jig plate according to embodiments of the present invention, the holding part of the jig plate body preferably holds the optical connector plug through a holding member for detachably holding the optical connector plug.

In a jig plate according to embodiments of the present invention, the holding member can preferably be replaced with a holding member of a different correction angle.

In a jig plate according to embodiments of the present invention, the optical connector plug is preferably held such

that the ferrule cylindrical member is brought into contact with a polishing surface of the polishing plate relatively at an angle so that the angle formed by the axial direction and a polishing surface closer to the rotation center than the ferrule cylindrical member becomes an obtuse angle.

An end face polishing method according to embodiments of the present invention is provided wherein a ferrule cylindrical member is brought into contact with a polishing member at a predetermined angle with a jig plate, the polishing member being placed on a rotating and fluctuating polishing plate supported by a polishing machine body and the jig plate fixing an optical connector plug having the ferrule cylindrical member holding an optical fiber; and the face of the ferrule cylindrical member is polished into a convex curve inclined with respect to a plane perpendicular to the axis. The target inclining direction of the polished convex curve of the ferrule cylindrical member is corrected so as to turn to a direction opposite to the rotating direction of the polishing plate with respect to a plane including the center of the jig plate body and the axis of the optical fiber so that the inclining direction of the polished convex curve of the ferrule cylindrical member held by the optical connector plug coincides with the reference direction of the optical connector plug.

In an end face polishing method according to embodiments

of the present invention, the ferrule cylindrical member is preferably brought into contact with a polishing surface of the polishing member relatively at an angle and is polished so that the angle formed by the axial direction and a polishing surface closer to the rotation center than the ferrule cylindrical member becomes an obtuse angle.

According to embodiments of the present invention, the use of a jig plate that polishes a ferrule cylindrical member in such a way that the target direction is determined in advance so that the inclining direction of a polished convex curve of the ferrule cylindrical member held by an optical connector plug coincides with the reference direction of an optical connector plug allows the inclining direction of the ferrule cylindrical member to coincide with the reference direction of the optical connector plug, thus reducing insertion loss during optical connection using the optical connector plug.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic sectional view of an end face polishing machine according to a first embodiment of the present invention;

Fig. 2A and Figs. 2B and 2C are a perspective view and sectional views of an example of an optical connector plug according to the first embodiment of the invention,



respectively;

Fig. 3 is a plan view of an end of the optical connector plug according to the first embodiment of the invention;

Figs. 4A and 4B are a perspective view and a side view of a jig plate according to the first embodiment of the invention, respectively;

Figs. 5A and 5B are a top view of and an enlarged view of the essential part of the jig plate according to the first embodiment of the invention, respectively;

Fig. 6 is a sectional view of the jig plate according to the first embodiment of the invention;

Figs. 7A and 7B are plan views of the end face of a ferrule cylindrical member according to the first embodiment of the invention;

Fig. 8A is a plan view of the trail of the ferrule cylindrical member and Figs. 8B and 8C are schematic plan view of the end face of the ferrule cylindrical member, according to the first embodiment of the invention;

Fig. 9 is a graph showing the relationship between the correction angle and the eccentricity according to the first embodiment of the invention;

Figs. 10A and 10B are an exploded plan view and a sectional view of an optical connector plug according to a second embodiment of the invention, respectively;

Fig. 11 is a perspective view of a jig plate according

to the second embodiment of the invention; and

Figs. 12A and 12B are a top view and a sectional view of the jig plate according to the second embodiment of the invention, respectively.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be specifically described with reference to the embodiments.

##### [First Embodiment]

Fig. 1 is a schematic sectional view of an end face polishing machine according to a first embodiment of the present invention.

As Fig. 1 shows, the center of a first rotation-transmission board 12 is secured to the rotation shaft of a rotary motor 11. A plurality of first connecting pins 13 is fixed on the concentric circle with the rotation center as the fulcrum of the first rotation-transmission board 12. The first connecting pins 13 are rotatably connected to the respective eccentric portions of a rotation-transmission board 14, to which second connecting pins 15 are fixed. Each second connecting pin 15 is rotatably connected to a second rotation-transmission board 16.

On the other hand, the center of a drive gear 18 is secured to the rotation shaft of a revolutionary motor 17. A driven gear 19 is in engagement with the drive gear 18. The

driven gear 19 is secured to the lower periphery of a revolution-transmission shaft 20. A bearing cylinder 22 of a polishing machine body 21 is fitted on the upper periphery of the revolution-transmission shaft 20. A rotary shaft 23 is rotatably fitted at a predetermined distance from the center of rotation into the revolution-transmission shaft 20. The lower end of the rotary shaft 23 is firmly fixed to the center of the second rotation-transmission board 16.

The upper end of the rotary shaft 23 is connected to a platen 25 via a joint 24. The platen 25 has the upper surface inclined toward the center in a cone shape and rotates clockwise and fluctuates in this embodiment.

A polishing member 27 is provided on the top of the platen 25 via an elastic member 26.

The materials for the elastic member 26 include rubber, elastomers, and resin.

The polishing member 27 provided on the elastic member 26 includes a polishing sheet having abrasive coating made of diamond, silicone oxide, cerium oxide, and silicone carbide and a polishing stone.

On the other hand, a jig plate 40 having optical connector plugs 100 that hold a plurality of ferrules is supported on the polishing machine body 21 with a support mechanism 30.

The jig plate 40 and the optical connector plugs 100 held

by the jig plate 40 according to the embodiment will now be described.

The optical connector plugs 100 held by the jig plate 40 of this embodiment will first be described. Fig. 2A and Figs. 2B and 2C are a perspective view and sectional views of the optical connector plug, respectively; and Fig. 3 is a plan view of an end of the optical connector plug.

The optical connector plugs 100 according to the embodiment is an LC optical connector plug, as illustrated, and includes a ferrule 110, a stopper 120, an urging spring 130 provided between the ferrule 110 and the stopper 120 for urging the ferrule 110 toward the axial end, and a plug housing 140 for holding the ferrule 110 and the stopper 120 therein.

The ferrule 110 includes a ferrule cylindrical member 111 made of ceramic such as zirconia or glass and a flange 112 provided at the rear end of the ferrule cylindrical member 111.

The ferrule cylindrical member 111 has a cylindrical shape with an outside diameter of 1.25 mm and has an optical-fiber insertion hole 113 therein in the axial direction for an optical fiber 1 to pass through.

The ferrule cylindrical member 111 has an end face 111a polished by an end face polishing machine into a convex curve inclined relative to a plane perpendicular to the axis, as shown in Fig. 2C.

Matching the center of curvature of the end face 111a of the ferrule cylindrical member 111 to the axis of the optical fiber 1 can reduce insertion loss during optical connection.

The flange 112 has an optical-fiber-core insertion hole 114 that communicates with the optical-fiber insertion hole 113 of the ferrule cylindrical member 111 and allows an optical-fiber core wire 2 having a coating on the outer periphery of the optical fiber 1 to pass through.

The flange 112 has a flange part 115 projecting around the circumference, on the outer periphery of the end thereof. The flange part 115 has a hexagonal cross section and engages with a rotation stopper of the plug housing 140 (specifically described later) to restrict the rotational motion of the ferrule 110 around the axis.

The plug housing 140 has a ferrule insertion hole 141 in the axial direction for the ferrule 110 to pass through.

The ferrule insertion hole 141 has a ferrule projection hole 142 having an inside diameter to project only the ferrule cylindrical member 111 when engaging with the end of the flange part 115 of the ferrule 110.

The end of the flange part 115 is in contact with the rim of the opening of the ferrule projection hole 142 so that the movement of the ferrule 110 toward the end is restricted.

The ferrule projection hole 142 has a rotation stopper

143 at the end adjacent to the flange 112, the stopper 143 coming in contact with the outer periphery of the flange part 115 to restrict the rotational movement around the axis of the ferrule 110.

The rotation stopper 143 has a hexagonal cross section, like the cross section of the flange part 115, and has a dimension to provide a space between it and the outer periphery of the flange part 115 so that the flange part 115 can move in the axial direction.

The space causes the ferrule 110 to rattle in the direction of rotation around the axis, with respect to the plug housing 140.

The ferrule insertion hole 141 has the stopper 120 fixed at the rear end thereof.

The stopper 120 has an optical-fiber-core insertion hole 121 in the axial direction for the optical-fiber core wire 2 to pass through, and has a communication hole 122 that communicates with the optical-fiber-core insertion hole 121 and has an inside diameter slightly larger than that of the optical-fiber-core insertion hole 121.

The difference in the inside diameter between the optical-fiber-core insertion hole 121 and the communication hole 122 provides a step 123.

The communication hole 122 holds the urging spring 130 therein, into which the rear end of the flange 112 of the

ferrule 110 is inserted.

When one end of the urging spring 130 comes into contact with the rear end of the flange part 115 and the other end comes into contact with the step 123 of the stopper 120, the ferrule 110 is urged to and held at the end of the plug housing 140.

The end face of the flange part 115 is in contact with the opening rim of the ferrule projection hole 142 while being urged toward the end, as described above, so that the ferrule 110 is held with the movement toward the end restricted.

In other words, the ferrule 110 is pushed toward the rear end against the urging force of the urging spring 130, thereby being moved toward the axial rear end.

The stopper 120 is fixed such that an engaging projection 124 of the stopper 120 and an engaging hole 144 of the plug housing 140 come in contact with each other.

A boot 150 formed of rubber or the like is fixed to the rear end of the stopper 120 to prevent the optical fiber 1 from breaking.

The plug housing 140 has a latch 145 on the outer periphery. The latch 145 is integrated with the plug housing 140 and is plastically transformable because one end is free.

The latch 145 detachably holds the optical connector plug 100 to the optical connector adaptor for optical connection and the jig plate 40, which will be specifically

described later.

The optical connector plug 100 needs to be polished so that the inclining direction 200 of the end face 111a of the ferrule cylindrical member 111, shown in Fig. 2C, coincides with the reference direction 201 of the optical connector plug 100, shown in Fig. 3.

The reference direction 201 of the optical connector plug 100 is used to position the optical connector plug 100 to an optical connector adaptor (not shown) in the rotating direction around the axis of the optical fiber 1. In this embodiment, the optical connector plug 100 is of LC type and the cross section of the plug housing 140 is shaped like a rectangle. Accordingly, the cross section of the insertion hole of the optical connector adapter for the optical connector plug 100 to be inserted is formed in the same rectangular shape as that of the plug housing 140, so that the optical connector plug 100 is positioned to the optical connector adapter in the rotating direction around the axis of the optical fiber 1. In other words, in this embodiment, the reference direction 201 is determined with the outer periphery of the optical connector plug 100 and the latch 145 as the reference; the direction orthogonal to a direction 203 orthogonal to the surface of the plug housing 140 of the optical connector plug 100 having the latch 145 is set to the reference direction 201.



The inclining direction 200 of the end face 111a of the ferrule cylindrical member 111 is a plane direction including an outermost protruding point on the outer periphery of the end face 111a and a rearmost protruding point, as shown in Fig. 2C. The inclining direction 200 includes the center of curvature that is the apex of the convex curve.

When the inclining direction 200 of the polished end face 111a of the ferrule cylindrical member 111 deviates from the reference direction 201, the center of curvature deviates from the axis of the optical fiber 1 to increase insertion loss when the optical connector plugs 100 are optically connected with each other, which will be specifically described later.

Therefore, it is necessary to polish the end face 111a of the ferrule cylindrical member 111 so that the inclining direction 200 of the polished convex curve of the ferrule cylindrical member 111 coincides with the reference direction 201 of the optical connector plug 100 to thereby reduce the eccentricity in the direction orthogonal to the inclining direction 200 including the center of curvature and the center of the optical fiber 1.

The jig plate 40 will then be described.

Figs. 4A and 4B are a perspective view and a side view of the jig plate 40 according to the first embodiment of the invention, respectively; Figs. 5A and 5B are a top view of

and a partially enlarged view of the jig plate 40; Fig. 6 is a sectional view taken along line A-A' of Fig. 5A; and Figs. 7A and 7B are plan views of the end face of the ferrule cylindrical member 111.

As illustrated, according to the embodiment, the jig plate 40 holds the LC optical connector plug 100 and has a jig plate body 50 having a plurality of concave holding parts 51 around the periphery along the circumference and a plurality of holding members 60 detachably held by the respective holding parts 51.

The jig plate body 50 is shaped like a polygonal disk and has the holding parts 51 each having a trapezoidal opening in the vicinity of the periphery along the circumference.

Each holding part 51 has a cylindrical tube 52, at the bottom, which is fitted to the end of the ferrule cylindrical member 111. The tube 52 has a through hole 53 in the axial direction for the jig plate body 50 to pass through along the thickness. The ferrule cylindrical member 111 of the optical connector plug 100 held by the holding member 60 is inserted in the through hole 53 and only the end of the ferrule cylindrical member 111 projects from the bottom of the jig plate body 50.

The tube 52 has an outside diameter that can be fitted on the end of the plug housing 140 of the optical connector plug 100. The end of the plug housing 140 comes in contact

with the bottom of the holding part 51, so that the amount of the ferrule cylindrical member 111 projecting from the bottom of the jig plate body 50 is controlled.

The holding part 51 and the tube 52 are provided at an inclination angle so as to hold the optical connector plug 100 by the jig plate 40 such that the rear end of the optical connector plug 100 is inclined from the center to the periphery, relative to the thickness of the jig plate body 50.

The holding member 60 held by the holding part 51 has a holding hole 61 for the optical connector plug 100 to pass through along the thickness.

The holding hole 61 has a latch engaging part 62 with which the latch 145 of the plug housing 140 of the optical connector plug 100 is brought in engagement. When the optical connector plug 100 is inserted into the holding hole 61, the latch 145 is brought into engagement with the latch engaging part 62 and thus the optical connector plug 100 is detachably retained by the holding members 60.

The holding member 60 have the same shape as that of the holding part 51 and is detachably retained by the holding part 51. It is sufficient to retain the hold member 60 to the jig plate body 50 so as not to become disengaged in the direction of the thickness of the jig plate body 50 and not to rotate around the axis of the optical fiber 1 with respect to the

jig plate body 50 and so the way of fixing is not particularly limited; for example, the holding member 60 and the jig plate body 50 may be fixed to each other with a screw (not shown).

The holding hole 61 in the holding member 60 retains the optical connector plug 100 while correcting the target direction of the inclination of the polished end face 111a of the ferrule cylindrical member 111 so as to rotate in the direction opposite to the rotating direction of the platen 25 with respect to the plane including the center of the jig plate body 50 and the optical fiber 1 so that the inclining direction 200 of the end face 111a, which is polished in convex curve, of the ferrule cylindrical member 111 retained by the optical connector plug 100 coincides with the reference direction 201 of the optical connector plug 100.

When the ferrule cylindrical member 111 is polished with the reference direction 201 of the optical connector plug 100 coincided with the direction of a plane including the axis of the optical fiber 1 and the center of the jig plate body 50, the ferrule cylindrical member 111 is rotated around the axis of the optical fiber 1 by the polishing member 27 since the ferrule cylindrical member 111 is held so as to cause rattle.

When the ferrule cylindrical member 111 rotates around the axis of the optical fiber 1, the inclining direction 200 of the inclined convex curve formed on the end face 111a of

the ferrule cylindrical member 111 deviates from the reference direction 201, as shown in Fig. 7A.

Since the deviation of the inclining direction 200 is formed on the convex curve where the end face 111a is inclined relative to the plane perpendicular to the axis of the optical fiber 1, the ferrule cylindrical member 111 is rotated with a point 212 different from the center 210 of the optical fiber 1 as the center.

Therefore, the center 211 of curvature formed on the end face 111a is formed eccentrically in the direction 203 orthogonal to the reference direction.

The eccentricity  $L$  ( $\mu\text{m}$ ) between the center 210 of the optical fiber 1 and the center 211 of curvature can be given by the following equation:

[Equation 1]

$$L = \gamma/1000 \times \sin\theta \times \sin\phi \quad (1)$$

where  $\gamma$  (mm) is the radius of curvature,  $\theta$  (degree) is the inclination angle of the end face 111a, and  $\phi$  (degree) is the rotation angle of the ferrule cylindrical member 111 relative to the plug housing 140.

The eccentricity of the reference direction 201 can be reduced by changing the contact angle formed by the axis of the ferrule cylindrical member 111 and the polishing member 27 through the use of the jig plate 40 or the platen 25. However, the eccentricity of the direction 203 orthogonal to

the reference direction 201 cannot be reduced even by changing the contact angle that the ferrule cylindrical member 111 makes with the polishing member 27.

Since the platen 25 rotates or fluctuates, the polishing trail of the ferrule cylindrical member 111 on the polishing member 27 becomes trochoid as shown in Fig. 8A. Fig. 8A is a plan view of the trail of the ferrule cylindrical member 111 and Figs. 8B and 8C are schematic plan view of the end face of the ferrule cylindrical member 111, respectively.

In the trochoid trail, a trail region a ascending the slope of the polishing member 27 has a large polished quantity on one side, as shown in Fig. 8B and a trail region b descending the slope has a smaller polished quantity than that of the region a, as shown in Fig. 8C, thus causing unsymmetrical wear.

In this way, also the inclination of the platen 25 causes unsymmetrical wear in polished quantity to increase the eccentricity between the center 211 of curvature and the center 210 of the optical fiber 1.

According to the embodiment, in order to handle the rattle of the ferrule 110 in the rotating direction around the axis with respect to the plug housing 140 and the deviation in polished amount, the holding hole 61 provided in the holding member 60 is formed to correct the inclining direction of the end face 111a so as to rotate in the direction opposite

to that of the platen 25 around the axis of the optical fiber 1 and the end face 111a is polished so that the reference direction 201 of the optical connector plug 100 and the inclining direction 200 coincide with each other, as shown in Fig. 7B. Thus the center 211 of curvature and the center 210 of the optical fiber 1 can be coincided with each other.

More specifically, as Fig. 5B shows, the holding member 60 holds the reference direction 201 of the optical connector plug 100 to the direction (target direction) rotated around the axis of the optical fiber 1 in the direction opposite to the rotating direction of the platen 25 with respect to the plane containing the center of the jig plate body 50 and the axis of the optical fiber 1. Thus the reference direction 201 and the inclining direction 200 are coincided with each other so that the center 211 of curvature and the center 210 of the optical fiber 1 are coincided with each other.

The eccentricity between the center 211 of curvature formed on the end face 111a of the ferrule cylindrical member 111 and the center 210 of the optical fiber 1 was measured when polishing was performed with the correction angle of the optical connector plug 100 held by the holding member 60 was set at zero degree, two degrees, and 2.5 degrees. The measurement is shown in Table 1.

[Table 1]

Correction Angle (degree)	0	2	2.5
Eccentricity ( $\mu\text{m}$ )	42.6	-9.2	-19.04

The measurement in Table 1 gives the approximate curves shown in Fig. 9. The approximate curves show that when the correction angle that is the angle of the target direction of the optical connector plug 100 relative to the plane containing the center of the jig plate body 50 and the axis of the optical fiber 1 is 1.5 degrees, the eccentricity becomes 0  $\mu\text{m}$ . Accordingly, in this embodiment, the correction angle of the optical connector plug 100 retained by the holding member 60 is set to 1.5 degrees as shown in Fig. 5B.

In practice, even when the correction angle is set at 1.5 degrees, the end face 111a with an eccentricity of 0  $\mu\text{m}$  is not formed on every ferrule cylindrical member 111, causing variation in eccentricity; however, the eccentricity can be reduced as small as 5  $\mu\text{m}$  or less.

Reducing the eccentricity can decrease the insertion loss when the pair of opposite optical connector plugs 100 is connected with the optical connector adapter.

The jig plate body 50 has a boss 54 serving as a mounting part supported by the support mechanism 30, fixed in the center thereof with screws.

On the other hand, the support mechanism 30 includes a



supporting part 31 provided to the polishing machine body 21 and an arm 32 movably held by the supporting part 31, as shown in Figs. 1 and 6.

The arm 32 retains the jig board 40 by the end thereof engaged with the boss 54 while restricting the rotational movement and the inclining movement of the jig plate 40.

Specifically, the boss 54 of the jig plate 40 includes a rectangular recess 56 and a lid 57 fixed to the opening end of the recess 56 and having an opening smaller than the recess 56.

On the other hand, the end of the arm 32 has a rectangular flange 33 in engagement with the recess 56. Inserting the flange 33 from the side of the boss 54 into the recess 56 brings the side of the flange 33 into contact with the side of the recess 56, thereby restricting the rotational movement.

The flange 33 inserted into the recess 56 of the boss 54 is brought into contact with the lid 57 to thereby restrict the movement of the jig plate 40 toward the platen 25.

The arm 32 thus retains the jig plate 40 while restricting the movement of the jig plate 40 in the directions of rotation and inclination.

The arm 32 that retains the jig plate 40 in that way is provided to the supporting part 31 so as to be freely moved along the thickness of the platen 25 and pushes the plurality of optical connector plugs 100 against the polishing member

27 on the platen 25 with a predetermined pressure.

Pushing means for pushing the arm 32 is not particularly limited; for example, the arm 32 may be pushed manually or by the driving of a drive motor or a hydraulic pump. The pushing means may include a pressure sensor such as a load cell for determining the data on the pressure to push the optical connector plug 100 to the polishing member 27.

[Second Embodiment]

The above described first embodiment has used the jig plate 40 that holds the LC optical connector plug 100 as an example. The second embodiment uses a jig plate that holds an SC optical connector plug as an example. Components same as those of the first embodiment are given the same reference numerals and their description will be omitted.

An optical connector plug held by the jig board according to the second embodiment of the invention will first be described. Figs. 10A and 10B are an exploded plan view and a sectional view of the optical connector plug 100A according to the second embodiment of the invention, respectively.

The optical connector plug 100A of this embodiment is an SC optical connector plug, as illustrated. The optical connector plug 100A includes a plug housing 140A that is fitted to the SC optical connector adapter, a plug frame 160 fitted in the plug housing 140A, a ferrule 110A that holds

the optical fiber 1 that performs optical connection and is inserted from the back of the plug frame 160, a stop ring 120A of which the end comes into engagement with the rear end of the plug frame 160, and an urging spring 130A held between the ferrule 110A and the stop ring 120A for urging the ferrule 110A toward the axial end.

The ferrule 110A includes a ferrule cylindrical member 111A made of ceramic such as zirconia or glass and a flange 112A provided at the rear end of the ferrule cylindrical member 111A.

The ferrule cylindrical member 111A has a cylindrical shape with the outside diameter of 2.5 mm and has an optical-fiber insertion hole 113A therein in the axial direction for the optical fiber 1 to pass through.

The ferrule cylindrical member 111A has an end face 111a polished by the end face polishing machine to be formed in a convex curve inclined relative to the plane perpendicular to the axis in a manner similar to the ferrule cylindrical member 111 of the first embodiment.

Matching the center of curvature of the end face 111a to the axis of the optical fiber 1 can reduce insertion loss during optical connection.

The flange 112A has an optical-fiber-core insertion hole 114A that communicates with the optical-fiber insertion hole 113A of the ferrule cylindrical member 111A and allows

the optical-fiber core wire 2 having a coating on the outer periphery of the optical fiber 1 to pass through.

The flange 112A also has a flange part 115A projecting around the circumference, on the outer periphery thereof. The flange part 115A has a circular cross section and has key grooves 116 fitted on engaging projections 163 of the plug housing 140A, which will be specifically described, at intervals of 90 degrees at four points around the circumference. The key grooves 116 engage with the engaging projections 163 of the plug frame 160, thereby restricting rotational movement around the axis of the ferrule 110A.

The number, position, depth, shape and so on of the key grooves 116 are not particularly limited and may be determined as appropriate depending on the plug frame 160 for positioning the ferrule 110A.

The materials for the flange 112A may include metallic materials such as stainless steel, brass, and iron. This embodiment uses stainless steel.

The plug frame 160 includes a ferrule insertion hole 161 drilled through along the length for the ferrule 110A and the urging spring 130A to pass through. The ferrule insertion hole 161 has a ferrule projection hole 162 having an inside diameter to project only the ferrule cylindrical member 111A.

The ferrule insertion hole 161 has the two engaging projections 163 therein that engage with the key grooves 116

of the ferrule 110A so as to project radially inwardly. The plug frame 160 has two engaging holes 164 communicating with the ferrule insertion hole 161 and open to the outer periphery. The plug frame 160 has an engaging projection 165 projecting radially outward from the outer periphery thereof.

The stop ring 120A that is fitted to the rear end of the plug frame 160 is made of a cylindrical metal having a penetrated optical-fiber-core insertion hole 121A that allows the optical-fiber core wire 2 to pass through. The optical-fiber-core insertion hole 121A has a communication hole 122A at the end for the urging spring 130A to pass through. The difference in the inside diameter between the optical-fiber-core insertion hole 121A and the communication hole 122A provides a step 123A.

The communication hole 122A holds the urging spring 130A therein, into which the rear end of the flange 112A of the ferrule 110A is inserted. When one end of the urging spring 130A comes into contact with the rear end of the flange part 115A and the other end comes into contact with the step 123A of the stop ring 120A, the ferrule 110A is urged to and held at the end of the plug housing 140A while being urged toward the end with respect to the plug frame 160, with the movement toward the end restricted. The key grooves 116 of the flange part 115A are fitted on the engaging projections 163 of the ferrule insertion hole 161, as described above, and thus the

ferrule 110A is held, with the rotational movement around the axis restricted.

The stop ring 120A has engaging projections 124A that project in the engaging holes 164 of the plug frame 160 around the outer periphery of the end of the stop ring 120A. Each engaging projection 124A has a tapered outer periphery of which the outside diameter decreases toward the end and is fixed by engagement with the corresponding engaging hole 164 of the plug frame 160.

On the other hand, the plug housing 140A has a shape that allows the plug frame 160 to be inserted and has an engaging recess 146 that engages with the engaging projection 165 of the plug frame 160.

The optical connector plug 100A has the plug housing 140A that has a rectangular cross section, which allows the plug housing 140A to be positioned in the rotating direction around the axis of the optical fiber 1 owing to the shape of the outer periphery when the optical connector plug 100A is connected to an optical connector adapter (not shown). The plug housing 140A can be connected to the optical connector adapter by 180-degree turn because of the rectangular cross section. Therefore, a projection 147 provided on the outer periphery of the plug housing 140A is brought into engagement with a groove provided in a device, and thus the optical connector plug 100A is positioned to the device in the

direction of rotation around the axis of the optical fiber 1.

In other words, the predetermined reference direction 201 including the axis of the optical fiber 1 of the SC optical connector plug 100A according to the embodiment is determined with the outer periphery of the plug housing 140A and the projection 147 as the reference.

With the optical connector plug 100A, the end face 111a of the ferrule cylindrical member 111A is polished so that the inclining direction 200 of the polished convex curve coincides with the reference direction 201 of the optical connector plug 100A.

In this embodiment, the direction orthogonal to the direction orthogonal to a plane of the plug housing 140A of the optical connector plug 100A, which has the projection 147, is set as a reference direction.

A jig plate 40A of the end face polishing machine for polishing the end face 111a of the ferrule 110A of the optical connector plug 100A will now be described. Fig. 11 is a perspective view of the jig plate 40A according to the second embodiment; and Figs. 12A and 12B are a top view and a sectional view of the jig plate 40A, respectively.

As illustrated, the jig plate 40A is provided on the end face polishing machine of the first embodiment for holding the SC optical connector plug 100A and includes a jig plate

body 50A having a plurality of the optical connector plugs 100A and holding members 60A for retaining the optical connector plugs 100A between them and the jig plate body 50A.

The jig plate body 50A is shaped like a polygonal disk and has holding parts 51A each having an opening with the same shape as that of the plug housing 140A of the optical connector plug 100A in the vicinity of the periphery around the circumference and detachably holding the optical connector plug 100A.

Each holding part 51A has a cylindrical tube 52A, at the bottom, which is fitted to the end of the ferrule cylindrical member 111A. The tube 52A has a through hole 53A in the axial direction for the jig plate body 50A to pass through along the thickness. The ferrule cylindrical member 111A of the optical connector plug 100A placed between the jig plate body 50A and the holding member 60A is inserted into the through hole 53A and only the end of the ferrule cylindrical member 111A projects from the bottom of the jig plate body 50A.

The tube 52A has an outside diameter that can be fitted to the end of the plug housing 140A of the optical connector plug 100A. The end of the plug housing 140A comes in contact with the bottom of the holding part 51A, so that the amount of the ferrule cylindrical member 111A projecting from the bottom of the jig plate body 50A is controlled.

The holding part 51A and the tube 52A are provided at



an inclination angle to hold the optical connector plug 100A by the jig plate 40A such that the rear end of the optical connector plug 100A is inclined from the center to the periphery, relative to the thickness of the jig plate body 50A.

The holding members 60A for holding the optical connector plug 100A with the holding part 51A are provided around the periphery of the jig plate body 50A, that is, portions corresponding to the holding parts 51A.

The holding members 60A each include a cylindrical column support 63 of which one end is fixed to the upper surface of the jig plate body 50A so as to be inclined in the same direction as that of the holding part 51A, a fixing part 64 engaging with the column support 63 for urging the rear end of the optical connector plug 100A, and a tension spring 65 on the outer periphery of the column support 63 and between the fixing part 64 and the jig plate body 50A.

The fixing part 64 is shaped like a cylinder and has a through part 67 having a column-support through hole 66 for the column support 63 to pass through and an arm 68 which projects radially from the side of the through part 67 and is engaged with the rear end of the optical connector plug 100A. The column support 63 is passed through the column-support through hole 66, so that the fixing part 64 is held movably in the axial direction of the column support

63.

The tension spring 65 is provided around the outer periphery of the column support 63 such that one end is fixed to the jig plate body 50A and the other end is fixed to the outer periphery of the fixing part 64, thereby urging the fixing part 64 toward the holding part 51A of the jig plate body 50A.

The column support 63 has a screw 69 screwed in the side thereof, the head of the screw 69 projecting from the side. The fixing part 64 has a recess 67a along the axis with a predetermined length, the recess corresponding to the projecting head of the screw 69. Engagement of the recess 67a with the head of the screw 69 restricts rotational movement of the fixing part 64 around the axis.

The fixing part 64 is urged by the tension spring 65 toward the holding part 51A of the jig plate body 50A, thereby clamping the optical connector plug 100A between the arm 68 of the fixing part 64 and the holding part 51A at a predetermined angle.

The optical connector plug 100A is retained in such a way that the fixing part 64 is first moved upward in the drawing against the urging force of the tension spring 65 to thereby increase the distance between the arm 68 and the holding part 51A, and thereafter the end of the ferrule 110A is passed through the through hole 53A in the tube 52A of the

jig plate body 50A and the fixing part 64 is urged toward the holding part 51A by the urging force of the tension spring 65, thereby clamping the optical connector plug 100A between the arm 68 of the fixing part 64 and the bottom of the holding part 51A. Thus the optical connector plug 100A is held while being urged toward the jig plate body 50A by the tension spring 65 of the holding members 60A. At that time, the end of the ferrule 110A held by the optical connector plug 100A projects by a predetermined amount through the through hole 53A from the surface opposite to the upper surface of the jig plate body 50A to which the optical connector plug 100A is held while being urged.

The jig plate 40A of this embodiment is also constructed, as in the first embodiment, such that the optical connector plug 100A is fixed by being fitted with the holding part 51A while correcting the target direction of the inclination of the polished end face 111a of the ferrule cylindrical member 111A so as to rotate in the direction opposite to the rotating direction of the platen 25 with respect to the plane including the center of the jig plate body 50A and the optical fiber 1 so that the inclining direction 200 of the end face 111a, polished in convex curve, of the ferrule cylindrical member 111A coincides with the reference direction 201 of the optical connector plug 100A. Therefore, the holding part 51A of the jig plate body 50A is arranged en advance so as to hold the

reference direction 201 of the optical connector plug 100A while correcting it to the direction (target direction) rotated around the axis of the optical fiber 1 in the direction opposite to the rotating direction of the platen 25 with respect to the plane containing the center of the jig plate body 50A and the axis of the optical fiber 1.

Thus even with the structure of the jig plate 40A for holding the SC optical connector plug 100A in which the holding part 51A is provided to the jig plate body 50A at a corrected angle and the optical connector plug 100A is directly clamped between the holding part 51A and the holding member 60A, the eccentricity between the center of curvature formed at the end face 111a of the ferrule cylindrical member 111A and the center of the optical fiber 1 can be decreased as small as 5  $\mu\text{m}$  and the insertion loss when the pair of optical connector plugs 100A is oppositely connected with an optical connector adapter can be reduced.

#### [Other Embodiments]

Although the embodiments of the present invention have been described, the basic structure of the jig plate and the end face polishing method is not limited to the above description.

For example, in the first embodiment, the optical connector plug 100 held by the holding member 60 is an LC optical connector plug and, in the second embodiment, the

optical connector plug 100A held by the jig plate 40A is an SC optical connector plug. The present invention, however, is not limited to that. With either structure of the jig plate 40 of the first embodiment and the jig plate 40A of the second embodiment, any optical connector plugs of an SC type, an FC type, and MU type, held by a plug housing such that the ferrule can move axially to cause rattle, can reduce eccentricity by the polishing according to the invention.

For example, the plug housing of the FC optical connector plug is shaped like a cylinder and includes a projecting location key therein. Such an FC optical connector plug is positioned to the optical connector adapter in the rotating direction around the axis of the optical fiber with the location key provided inside the plug housing. Therefore, the reference direction of the FC optical connector plug is determined with the location key as the reference. Thus the predetermined reference direction including the axis of the optical fiber of the optical connector plug may be determined as appropriate depending on the outer shape and the location key for positioning in the rotating direction around the axis of the optical fiber when connected to the optical connector adapter.

According to the first embodiment, the holding member 60 corrects the reference direction 201 of the optical connector plug 100 by 1.5 degrees with respect to the plane

including the center of the jig plate body 50 and the axis of the optical fiber 1. However, the invention is not limited to that. For example, it is also possible to provide a plurality of holding members with different correction angles and to replace the holding member as appropriate depending on the rotation angle of the ferrule 110 relative to the plug housing 140 due to the rattle.

According to the second embodiment, the jig plate body 50A includes the recessed holding part 51A to hold the optical connector plug 100A between the holding part 51A and the holding member 60A. However, the holding part of the jig plate body may include a detachable holding part capable of holding a detachable optical connector plug, as in the first embodiment. Accordingly, it is also possible to prepare a plurality of holding members corresponding to the shape of the optical connector plugs of SC type, FC type and so on to share the jig plate by the plurality of optical connector plugs.

According to the invention, the end face of a ferrule can be polished so that the apex of the convex curve of a ferrule cylindrical member and the center of curvature coincide with each other even in the state of the optical connector plug that holds the ferrule cylindrical member. This allows insertion loss to be reduced also during the optical connection between the optical connector plugs.